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Possibilities of Using Modified High Property Concretes in Modern Construction

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ABSTRACT

This article shows high performance concretes' role in modern construction and their effectiveness improvement processing method analysis. It was found that in present time and near future modified high performance concretes would be on high demand in construction works, which includes unique buildings and structures erection, in substitution of traditional concretes and mortars. It was defined that there are few main principles and criteria for structuring speeding and, in result, speeding of cement compositions hardening. One of which is mortar high degree supersaturation by solution products of clinker minerals in relation with crystalizing crystalline hydrates and sustaining this high supersaturation during all period of cement hydration crystallizing process until shielding is formed over cement grains. It was showed that given requirements are achieved by next methods: using extra-strong Portland cements, reducing water ratio due to water-reducing admixture, using krents admixtures. It was discovered that lately krents admixtures, functioning as the structuring center, became more widespread. This work contains complex of modifiers, based on micro silica and plasticizer admixtures on basis of carboxylate resin. Micro silica is soot, particles of which represent amorphous silica specks with average cement finesses of near 20 sq m/g as a filler. Replacing part of the cement with micro silica allows highly implement super plasticizer fluxing action, and reduce water discharge in the dispersed system under the same gravity flow in 10 times comparing to normal slurries, and partially bond hydrated lime weak coarse-crystalline phase into hydrated calcium silicate, additionally strengthening cement brick structure and concrete on its basis. Article authors states that one of the most important methods of getting super concrete is use of high alite cement with concrete mixes low water/cement ratio with complex admixtures, based on plasticizers. In this case, balancing and hard aggregate close packing in all parts allows getting concrete with optimal structure and minimum void ratio.

KEYWORDS
Modified high performance concretes; getting basis; concrete technology; possibilities of using modified concretes; information service; construction ecologization; branch (field).

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Introduction

In terms of volume, technical and economical indexes level, concrete and ferro-concrete are at the forefront of world's construction material industry general structure (Cast-in-situ construction on Russia territory: history and development prospects, 2015). Received the name "material of the XX century", concrete remains main constructional material in the XXI century as well. Thus, issues of increasing

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its technical properties, strength and working life are still existing (Bazhenov et al., 2006).

Over the last years all industrialized countries have increased using of high performance super concrete (HPC) with compression capacity more than 60 MPa, what allows decreasing material consumption and raising building and construction parts working life in relation to normal concrete constructions with strength of 20-40 MPa. Last decade shows increasing of constructions concrete strength up to 130-150 MPa. Thus, since 1965 up till now concrete strength has increased in 2.0-2.5 times (Kuladzhi et al., 2015; Bazhenov et al., 2008; Lesovik et al., 2012).

Unfortunately, super concretes are on low demand in Russia. Concretes of average strength, used in Russia, are two times lower than in the USA and in 30-50% lower than in Europeans countries (GB/T 50080-2002, 2002; GB/T 50081-2002, 2002; GB/T 50082-2009, 2009; ASTM C1202-05, 2005; Ng & Plank, 2012; Fernandes et al., 2007; Felekoglu, 2008). Maximum concrete strength, as defined by its type regarding to SNiP (construction rules and regulations), for buildings and structures construction stands at B60 (M800). New edition of GOST 26633-91 (1991) defines maximal concrete type B80, which corresponds to the closest strength stamp M1000. Supper concrete effective constructions make out 0.5% from the total volume in Russia, more than 1.0% from the total volume in the USA and more than 10% in Norway (Bazhenov et al., 2006). Over the last years, range of institutes and organizations were intensively researching and developing super concrete usage, in particular, one based on cementing water reducer (CWR), and using effective plasticizers and ultra-disperse fillers. However, regardless CWR high properties, cement manufacturers did not master these cementing materials batching process over the last 10 years (Hosking & Pike, 1985; Yool et al., 1998; Ramirez et al., 1990; Muñoz et al., 2010).

Market economy development starts to change formed tendency and nowadays in Russia concrete types B15-B35 (M200-M400) are being, though rarely, on demand as well as super concretes of V40 and higher types (Murtazaev et al., 2015b; Fedosov et al., 2010). It is believed, that in future the main accent in concrete batching development will be not on materials saving, like cement, but getting high performance competitive concretes, which includes concretes of high initial and characteristics strength (Fagerlund, 1977; CCES-2004, 2004; Topcu & Ugurlu, 2003).

To produce super concretes of B100-B140 (M1200-1500) type, high quality cements, washed classified sands and fine-grain chippings of 3-10/3-12mm fraction from high strength rock formations, high-disperse micro silica or dehydrate kaolin and super plasticizer are needed firstly. Unfortunately, cements of PC-550 and PC-600 stamps became rarely used in Russia, and producing PC-500 cements usually loose before imported cements in strength indexes for 7.28 and 90 days.

Nowadays, usual traditional concretes are being replaced by complex concretes, which use both individual chemical modifiers that improve concrete mixes placeability and increase its physical and chemical indexes, and complex admixtures that include up to dozen individual chemical admixtures of different functional use. Reaction fine-grain mineral component of natural or man-made origin and concrete reinforcement elements play special role in concrete structure modification.

At present time, high performance super concretes are represented in different national and international regulations and codes in the next way:

- Norwegian regulations NS 3473: up to B105 type including, what is approximately equal M1200-M1300 stamps;

- Swedish regulations: up to B75 type including, what is approximately equal M900-M1000 stamps;
- Japanese regulations: up to B80 type including, what is approximately equal M1000 stamps;
- Western German and French regulations: up to B60-B65 type including, what is approximately equal M800-M900 stamps;
- British regulations BS 8110: up to C(80)-B(80) type including;
- Technical guidance notes of Romania C-137/1 – 89: up to M800 stamp including;
- Russian regulations GOST 26633-91 up to B80 type including, what is approximately equal M1000 stamp;
- New European Standard EN206 "Concretes" shows maximal heavy-weight concrete type – C115 and light-weight type – C80.

Materials and methods

For the high performance super concretes objective evaluation, criteria and tolerance ranges, covered by normal concretes standard methods tests should be defined as well as correctly interpreted results gained by comparing different control methods.

Results and discussions

Modern concrete technological properties have found its full acceptance in high performance concrete batching and manufacturing. This expression, accepted in 1993 by IFSC modern working group, combines complex concretes with high operating capacity, strength, working life, low diffusion coefficient and hardness index, reliable protection properties in regard to reinforcement, high chemical attack and bactericidal resistance, and volume stability (fig. 1).

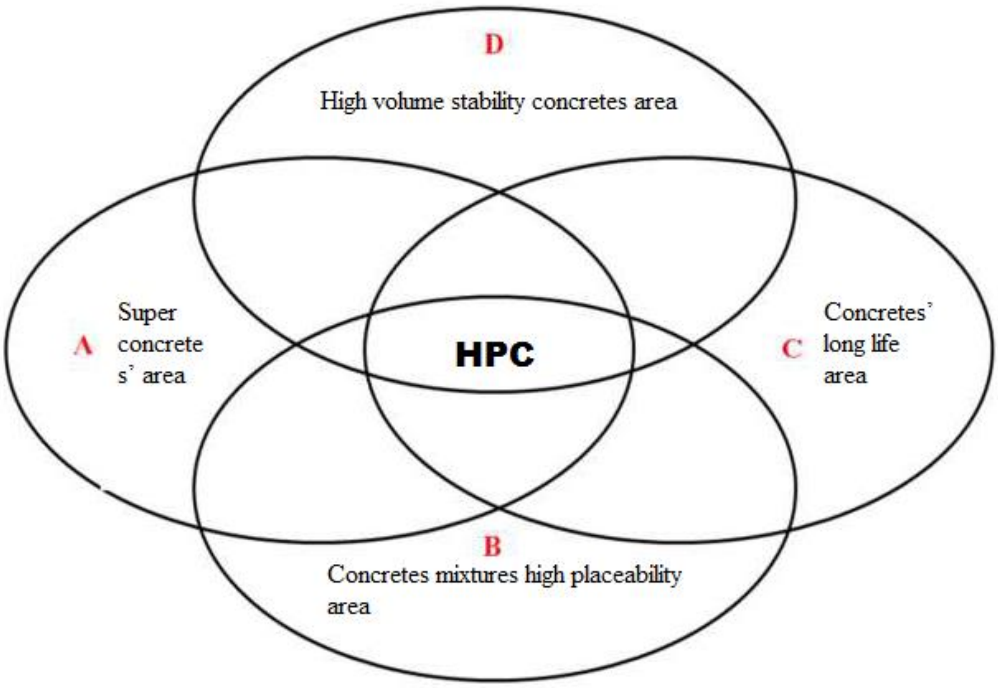

Figure 1. High performance concretes (HPC) conception graphical format

According to Japanese researchers long-life of these concretes nears to 500 years. Regardless some differences in various schools approaches, it can be stated that high performance concretes main criteria are:

- High strength, including initial strength (R28 = 60…120 MPa and higher, R1 – not less than 20…30 MPa);
- High frost resistance (F 400 and higher);
- Low permeability to water and chemical ions (W 12 and higher);
- High hardness index (not more than 0.4 g/sm^2);
- Low water absorbability (not less than 2.5% of the weight);
- Low absorbing capacity;
- Low diffusion coefficient;
- High resistance to chemical attack;
- High elastic module;
- Bactericidity and fungicidity;
- Regulated deformability indexes, including shrinkage compensation of 14…28 days aging.

Nowadays, high performance concretes, made of high workability and cast concrete mixes with limited water content, have two days compression capacity of 30-50 MPa, and 28 days of 60-150 MPa, frost resistance not less than F 600, water proof of W12 and higher, water absorbability not less than 1-2% of the weight, hardness index not more than 0.3-0.4 g/sm^2, regulated deformability indexes, including shrinkage compensation of 14-28 days aging, high gas-impermeability. In real conditions, predicted working life of such concrete exceeds 200 years. There is a possibility of getting permanent concretes with working life up to 500 years, what is confirmed by researches of the Japanese scientists (Bazhenov et al., 2006; Fedosov et al., 2010; Kudryavtsev, 2006; Batrakov, 2001; Komokhov & Shangina, 2002).

It is clear, that new materials, new concrete and ferro-concrete technology and new culture of manufacturing and thinking are required for building such high-rise erections critical structures.

High performance concretes technology is based on concrete structuring control on all stages of the manufacture. High performance Portland-cement, composite binders, concrete structure and properties of chemical modifiers complexes, active disperse mineral components and fillers and expansion agents are used for this (fig. 2). Intensive technology is used for concrete batching, ensuring sample precision, intimate mixing and pre-blending of the mix, its proper thickening and hardening. If needed, mechanic-chemical activation of the mix is used (fig. 3).

Considering that world's cement manufacturing overcame 1.5 billion tons a year, world's volume of concrete using reached 2.5 billion m^3 (Murtazaev et al., 2015a). It is one of the most large-scale materials defining development level of the civilization. Along with that, concrete is the most complex artificial compositional material that can possess quite unique properties. Concrete is used in quite different working conditions, balances well with the environment, has unlimited raw material source and relatively low price. Without doubts, that is why concrete will remain main constructional material in the future.

Super concretes appeared in foreign practice at the beginning of 60-ies. At this time, USA, Norway and some other countries started to use concrete with strength of 40 MPa in industrial scale. In 1965 there was marked usage of concrete with strength of 52 MPA, than in 1972 concrete's strength increased up to 60 MPa, and in 1982 to 75 MPa. In the same year, concrete with strength of 95 MPa was created on a trial basis. In the next years, concrete's strength rose to 130 MPa. At the present times, commercial supplies of concrete with strength of 150 MPa and higher are carrying out for block stone and post tensioned concrete structures. Today there are more than 100 buildings from 20 to 80 floors in the USA built with super concrete.

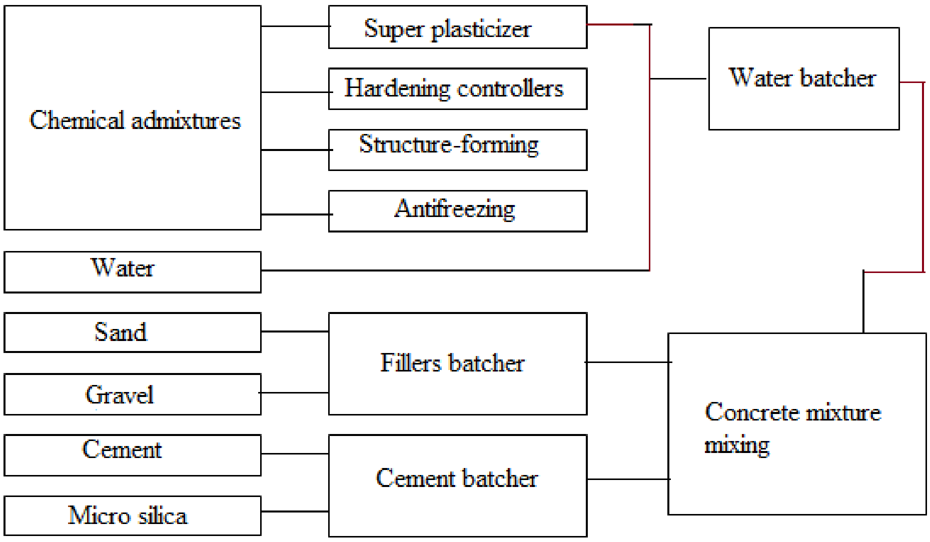

Figure 2. Technological scheme of batching high performance concrete mixes with micro silica

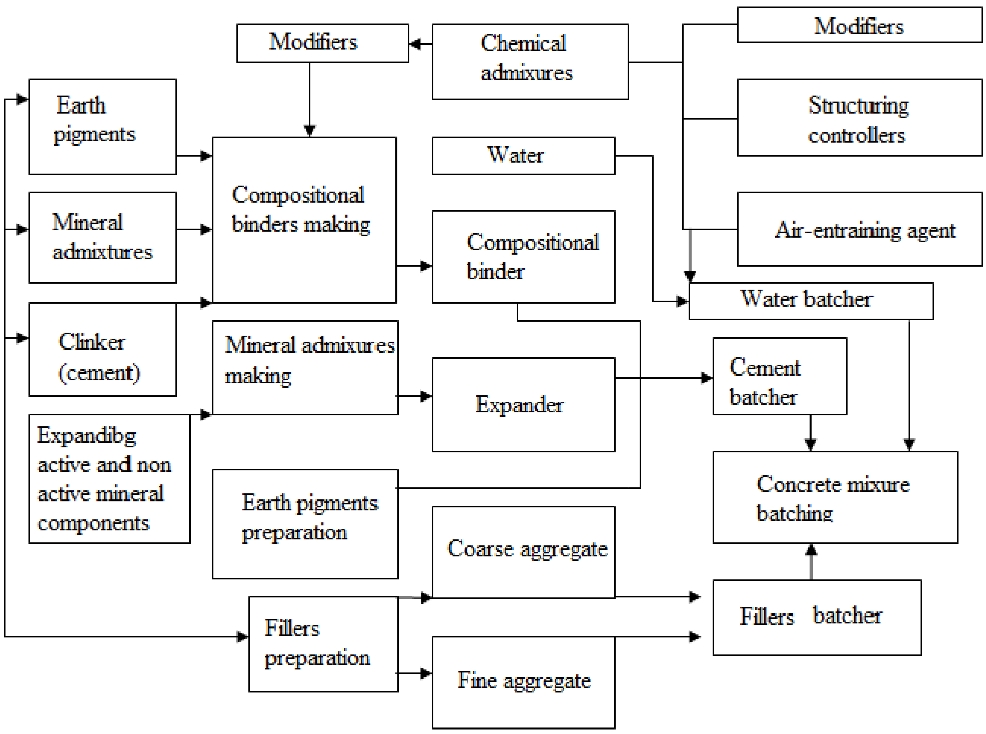

Figure 3. Technological scheme of high performance concrete mixes with compositional binders manufacturing

Introduction of super concrete started new era in construction. Its unique properties enabled to implement such construction objects as 163-storied skyscraper

Burj Khalifa in Dubai (828 m, the tallest ever existing construction in the world), English Channel tunnel, and 120-storied Abraj Al Bait towers in Mecca (601 m), 125-storied skyscraper in Chicago, bridge over the strait of Akashi in Japan with central bay of 1990 m (world's record of 1990), Petronas double skyscraper in Kuala-Lumpur, Malaysia and lots of others.

Over the last years geography of using super concrete has widened, and now it is used in different regions around the globe. Increasing of super concrete usage became possible due to technology development and demand of super concrete. Construction of high-rise buildings with reinforced concrete frame, long span cable bridges with reinforced concrete beam, offshore platforms and other special structures would be impossible without use of super concrete.

Super concrete starts to be widely used in precast structures of site prefabrication. Though, maximal concrete's strength of precast structures hasn't reached the limits of solid construction, there are examples of project designs and experimental usage of concrete with strength of 80-100 MPa in precast prestressed concrete constructions abroad (Bazhenov et al., 2006; Murtazaev et al., 2015a).

Main areas of cast super concrete usage are columns and heavy loaded cast structures, in particular long span roof constructions.

Regardless wide possibilities of modified super concrete's use in construction, unfortunately, such concretes with high strength are not highly demanded in Russia. It is predicted that further main accent in concrete industry development in our country would be on getting effective high quality and competitive materials: fast hardening concretes with high initial and characteristic strength, finely dispersed powder concretes, fiber reinforced concrete with different fiber types, self-consolidation concrete and others. Herewith, one should consider that materials, used for super concrete batching have higher requirements than materials for the normal concrete. While developing super concrete proportion, right choice of cement, expanse of what is quite high and makes up 400-500 kg/m^3, has a great role. Range of countries, including Russia, undertakes measures in creating super concretes (100 MPa and higher), which you can get in different ways: processing cement-water paste by jarring operation, pressing under high pressure.

Conclusions

Thus, modified super concretes, defined by range of positive characteristics (high strength, hardness and frost resistance, reliability, long life, etc.), at present times and near future will definitely be on high demand and be widely used in modern construction in replacement of traditional concretes and constructional mixtures.

It was observed that modified high performance concretes can be made using complex local natural and secondary raw materials. Questions and issues regarding multipurpose modified high performance concretes technology improvement, including high-rise function with fillers enrichment technology and concrete mixtures modification with mineral pozzolanic additions and super plasticizers, are of great current interest and need answers. Besides, by this time a great world's experience of high performance concrete batching, which should be implemented within the country, is already gained.

Disclosure statement

No potential conflict of interest was reported by the authors.

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